1 **Laser welding is an established technology used in the manufacture of powertrain components. DaimlerChrysler's Indiana Transmission Plant has made several advances in laser workstation designs which have yielded higher throughput.**

The Indiana Transmission Plant (ITP) is one of two DaimlerChrysler manufacturing facilities that have been able to engage in new technology advances. Unfortunately, these advances have not all come about without their share of problems. Today, I will discuss the changes made to previously used processes and workstation designs in the Powertrain division.

2 **High energy welding began at Chrysler's Kokomo Transmission Plant in the early 1970's with the introduction of electron beam laser systems. Although E-beam systems are still in use today, CO2 lasers have surpassed them in powertrain welding.**

In 1987 the first 9 Convergent Energy 6-kilowatt CO_2 lasers went into full production. In 1995 Chrysler began its largest laser installation by adding an additional 12 Convergent lasers ranging in power from 6 to 14 kilowatts. By the end of 1996 the total laser power available was 180 kilowatts! If this wasn't enough, three more systems were added over the next two years increasing the total laser power capacity to 210 kilowatts for twenty-four systems. KTP added two new lasers from Trumpf in 2001 with power outputs of 6 and 8 kilowatt to bring the combined laser power to 224 kW. The new lasers with higher power density were able to weld at the same rates by which the higher kilowatt Convergent systems had been using for years past.

3 **The second Powertrain facility, the Indiana Transmission Plant began production in late 1997. Once again, the plant began with 11 high-powered CO2 lasers, all of which were 14 kilowatts. Within a year, two additional laser systems were purchased with manual workstations that could quickly be changed over to support any production needs. This increased the number of lasers to 13 and a combined output of 182 kilowatts. In 2000, production demands required additional welding capacity and 7 new Trumpf lasers and workstations were added with output powers of 6 and 8 kilowatts. This increased the number of lasers to 20 and a total laser output power of 232 kilowatts. Unfortunately, the increased numbers of lasers were needed to supplement the shortfalls of the existing equipment.**

4 **The dilemma ITP faced was the fact that the machine builders, who DaimlerChrysler had been using for 15 years, had not improved their machine designs, and the common problems that had been encountered for years were accepted as part of everyday business.**

5 Powertrain plants have used the same machine builders for nearly 15 years and have continued to accept the shortfalls of the system because of a familiar mind set represented by the quote, “this is how it has always been done”. This has been what I feel the primary downfall for advancing the technology of lasers in automotive applications especially in Powertrain for quite some time. Advances in technology however do come with risk more often than not! Nevertheless, careful planning and application knowledge will allow for minimal risks.

In order to break the stalemate with the machine builders, we took on the task of working with each system integrator to discuss the ongoing problems with the current systems. This was used to determine what worked and what didn’t work. This wasn’t an easy thing for some integrators to accept, but the integrators that were willing to listen have responded to the challenge and are now thinking “outside of the box”! What we are trying to do is take proactive action and break the path toward new technologies instead of reacting to it. Understanding the processes and their variables has allowed ITP to create several new workstations and tooling designs that complement the production process instead of adding complexity to it.

6 **As a manager, my concern is not only with creating a robust process, I want to identify the needs of the plant like; decreasing operating costs, and reducing maintenance time to a benchmark level. In addition to the workstation, one must not forget about the power source selection. DaimlerChrysler in the U.S. has been using high power CO_2 lasers for deep penetration welding ranging from 6 to 18 kilowatts and work piece feedrates of 80 to 180 inches per minute. The costs for each transverse flow laser generator of this power range are roughly $650,000 without a workstation. If you then add in the workstation cost, the complete system is over $1.5million. To make this process even more unattractive for manufacturing, the maintenance cost and downtime are usually very high! To support 13 similar systems, ITP must also maintain spare parts inventory of well over $400,000 and have a skilled work force capable of making repairs and performing optical alignments to the generators.**

7 **To be competitive in an ever-changing marketplace, the manufacturing systems used for laser welding must be cost effective. ITP has not only been able to create new workstations through direct interaction with system integrators, but we have also introduced real-time process controls utilizing the primary infrared emission from the weld pool.**

The first step to creating the ultimate welding system is to identify the needs of the process. We have chosen to replace the current 14-kilowatt laser generators with lower power lasers yielding higher beam quality. These new systems also offer energy savings as well, because of their size and characteristics. The old systems at ITP are transverse flow lasers, which have been the workhorse of the industry in the past. Unfortunately, these systems were only capable of achieving a power efficiency of less than 10%. The new axial flow generators not only save on laser gasses needed, but they produce a much higher beam quality with a high power density. Even though the new laser systems are half the power of the older systems, the beam quality that is generated enables it to achieve and sometimes exceed current feedrates depending on the weld depth.

ITP has added a duplicate automated manufacturing line to meet the increased production needs of the 45RFE transmission except for the lasers and workstations. The new automated welding line uses Trumpf TLF6000 and TLF8000 lasers to perform all seven of the laser welds. Each workstation was equipped with twin work spindles to maximize throughput. (this can be seen in the two pictures below)

The Trumpf lasers have been in operation for two years and have already proven to be virtually maintenance free in comparison to the old Convergent lasers. Gas consumption for the new system versus the old is less than half and power consumption is one third that of the Convergent lasers.

8 **Now let's look at the old workstation designs.**

Both slides show the operation of the original laser workstations and beam delivery system. The existing workstations are single spindle systems that use a separate dial table to press parts and then transfer them into the welding cell. This design currently operates at a machine cycle time of 15 to 18 seconds' part to part. But the problems with this workstation all begin with the material-handling portion of the system, which have caused most systems to be slowed down to achieve a machine cycle time range of 16 to 20 seconds. Maintenance records also revealed that the laser workstation accounted for 45% of the total laser downtime.

9 **Besides the downtime issue, another problem is the design of the tooling. Much of the tooling has locating datum tolerances of 0.020" making seam position and spot size critical. Then to compound matters more, the spindle raises the part up into the weld station approximately 12 inches. Now add the runout of the spindle, which can be anything from .006 thousandths to .030 thousandths and the chances of welding off of the seam have increased substantially. Because of the inconsistency in the fixturing, a wider laser spot size and higher power laser has typically been used to correct for the short falls in the tooling and the workstation designs.**

10 **The new automated workstations were created using a machine tool approach and careful benchmarking of system integrators. The Trumpf TLC40 workstations were chosen because they partially satisfied the production requirements with two spindles and flying optics to increase the machine throughput. (Shown here are the beam delivery, twin sliding spindles and press station)**

11 **The new spindles consist of pull down collets or arbors, which maintain the part position during the weld process. Runout on these systems typically is found to be within five tenths of an inch. These types of tooling tolerances have only been seen in turning machines until now. Each of the seven new workstations use collets and twin spindles for welding, while part handling in and out of the workstation is done with the use of an overhead gantry. Machine movements were also minimized and the parts are no longer raised up to the weld head, instead the spindles slide forward with the parts to be welded. All part flow through the workstation is done in a linear fashion to simplify the automation complexity. The total cost for the new automated work cells are $1million, significantly less than the previously used workstations.**

12 **ITP also had a unique request for a universal welding cell that has the capability of welding any of the eleven components currently manufactured. This idea sounds fairly easy except for the next requirement, it must be able to be changed over in less than 1 hour and be performed by an operator. What this meant, is that the workstation must be able to weld horizontally as well as vertically and have tooling and shield gas tubes that are easily changed and require no operator intervention positioning the beam.**

13 **The work cell has its own press station that is equipped with modular tooling to provide quick changeover. Because of the simplistic design only one operator is required to run the work cell which is capable of producing up to 800 pieces per shift.**

14 **Working together with our chosen machine integrator, spindle and press fixturing was designed to be light weight and easy to handle. The upper weld tooling was cumbersome and awkward to load so the new tooling was designed to be installed using the work spindle hydraulic lift. This was achieved by using specially designed locking pins that would hold the upper tool in position when raised into the weld chamber. The loading tool would also be used to release the tooling when the unloading tool was raised back up into the chamber. Once these components are in place the operator selects the desired part program from a menu and pushes cycle start. The beam delivery system and the shield gas tube tooling all move into position automatically.**

How long has the setup process taken? Less than five minutes! Because of tooling designs and on screen instructions any operator can achieve the five-minute changeover.

15 **The idea behind the universal workstation was flexibility! This system can easily be retooled to run new components without high costs. The base machine has also been carried forth into the next generation system that is even easier to setup and can also be automated if needed! This slide shows the workstation and its upper tooling with quick change three jaw chuck tooling. The new designed workstation now has multiple position chuck jaws and quick-change upper tooling.**

This workstation is an example of how machine integrators have responded to DaimlerChryslers needs, the complete workstation and laser was designed and built in less than 16 weeks.

16 **This slide shows the previous workstations now equipped with twin spindles, gantry load & unload automation, beam switch and collets. This example shows how directly working with the machine builder can result in greater throughput and more robust machine designs. Working with the machine builders I have been able to stimulate the design process to achieve a win win situation for both DaimlerChrysler and the integrator. Through the utilization of our expertise in welding and manufacturing, we have finally been able to break away from inefficient designs and think outside the box to better design equipment and welding processes.**

17 **Now let's look at process and quality control systems at ITP. In the past, all laser welds were checked by the use of an ultrasonic test scan. These systems were very expensive sometimes in the realm of $200,000 and up depending on the amount of automation and the type of probe needed to perform the scan. Many of the ultrasonic testers used shear wave probes that could only scan half of the weld joint with any accuracy because of the material thickness. Unfortunately, the systems rarely repeated with any accuracy due to the tooling designs of the part holding fixtures. Because these systems were automated, the part holding tooling was designed slightly oversized to allow for easier pick-n-place robot loading. This caused false rejects to be detected by the systems and verification of system functionality as well as probe position always falling subject to many debates! Ultimately, these systems proved to be less reliable then expected and were only causing significant amounts of downtime leading to reduced throughput efficiency of the line.**

18 **To answer the needs of production, real time weld process monitors were chosen to replace the ultrasonic testing. For nearly four years, I have been working with Spawr Industries developing a real time monitoring system that gathers its data from the primary emissions of the weld pool. The Spawr system is non-intrusive to the beam delivery components! The monitor is co-axial with the high power beam and has the sensor head mounted up-stream from the focus module. The typical system consists of a computer, data analysis box and sensor head, which can be installed within one hour and able to acquire weld data within 30 minutes after installation. To further make the process monitor more attractive the entire system cost is under $25,000.**

19 **Let's take a closer look at the Spawr process monitor and how it works! The monitor has a variable sampling rate of 100 Hz to 10 kHz and a signal to noise ratio of approximately 3000 to 1. The sensor head is compact, pre-aimed and requires no maintenance, while also exhibiting no sensitivity to machine vibrations. The process monitor has been successful in identifying surface contaminations, cover gas anomalies, laser power fluctuations, and part fit up errors, as well as being able to locate the optimum focal point.**

The following slides will show some examples of the weld signatures that were created with the Spawr process monitor.

20 **The first signature shows a weld being performed without cover gas, as you can see the signal level has increased and there is a significant amount of eruptive activity coming from the melt pool.**

The second signature shows the same weld only this time with cover gas, as you can see the signal is substantially lower and there are virtually no surface anomalies shown.

21 **The next two slides show how the monitor can locate the prime focal point of a high power laser beam. The slide shows a typical signature for a CW laser moving through the prime focus point. The peak signature indicates prime focus, which is the highest irradiance power density of the focused beam.**

22 **To understand this concept further or use the monitor as a diagnostic tool, a chopper was used to segment the beam as the work piece was rotated on a 5-degree angle. You can see how the signal increases as the part moves into sharp focus and then decreases as the part moves out of focus.**

23 **This slide indicates an actual passed weld file. The weld file displayed consists of a seal pass and a weld pass. Because the seal pass data is not being used to determine the pass or fail condition the process limits are set to gauge the weld pass only.**

24 **This is the same weld except the shield gas tube was moved off location. As you can see there is a significant increase in the irradiance from the melt pool due to lack of cover gas generating the failed weld signal. Because the real time process monitors have proven to be reliable, ITP has reduced the amount of destructive part testing to require only two parts per shift.**

25 **Understanding the advantages of real time process monitoring has reduced the frequency of destructive testing to twice per shift. ITP and Spawr are working to close the process loop and let the system take control of certain parameters to ensure the quality of the welds produced. The next generation laser systems will hopefully be closed loop systems that will virtually remove the human factor from the equation. Proper monitoring of key characteristics associated with deep penetration welding will enhance the system performance and alert operators prior to system failures. ITP is moving in this direction in order to make the systems more user friendly and remove the mystery of laser welding on the manufacturing floor!**

In closing, DaimlerChrysler together with its laser integrators have been able to develop new laser systems and process controls that have provided lower maintenance cost's and improved throughput.